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TITLE

EFFECT OF HIGH AIR TEMPERATURE ON THE BEHAVIOR OF IPS ADULTS

Results of 1950 Studies at Miami Field Base

by G. R. Struble

Forest Insect Laboratory
29 Forestry Bldg., U. C.
Berkeley 4, California
June 27, 1951

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SUBJECT—

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

WASHINGTON, D. C.

Forest Insect Laboratory
29 Forestry Bldg., U. C.
Berkeley 4, California

July 11, 1951

To: Dr. J. A. Beal, in Charge, Forest Insect Investigations

From: F. P. Keen, in Charge, Berkeley Laboratory

Subject: Struble's report on "Effect of High Air Temperature on the Behavior of Ips Adults"

I am enclosing a report by Struble covering an experiment he conducted last summer to determine something about the effect of high temperatures on various habits and behavior of Ips adults. While he was unable to get as much of a spread in temperature as had been desired, the tests did show that an optimum effect was obtained on adults with temperatures between 80° and 94° F.

Since Ips beetles have various ways of escaping excess heat, I believe it is safe to conclude that we cannot expect control to result from a hot summer. While the experiments were not as productive as Struble hoped, the report does contain some new and interesting observations on the behavior of Ips adults when subjected to high temperatures.

cc: Furniss
Orr
Evenden
Wygant

EFFECT OF HIGH AIR TEMPERATURE ON THE BEHAVIOR OF IPS ADULTS

Results of 1950 Studies at Miami Field Base

by G. R. Struble

INTRODUCTION

Previous studies on the Ips problem in an attempt to determine the cause of periodic outbreaks in reserve ponderosa pine stands indicated that temperature may be highly important in its effect on adult behavior in establishing attacks and progeny. During 1950 an experiment was undertaken to test the effect of prolonged temperatures within the maximum range of activity in inducing changes of habit believed responsible for brood failures. The points to be determined were the effect on (1) emergence, (2) flight, (3) attack habits, (4) mating habits, (5) feeding habits, (6) reproduction, (7) longevity.

This experiment was conducted during a six-week period in July and August in an open freshly cutover Site II ponderosa pine area, elevation 4800 feet, near Miami field base. Because of many refinements required in developing technique, the results obtained are preliminary and cannot be used as a basis for conclusions. They are of interest particularly in the considerations that may be given to further studies on temperature in influencing bark beetle behavior.

PLAN OF EXPERIMENT

Provision for high temperatures was made through the use of 12' x 14' wall tent enclosures which heated readily with sun exposure when tightly closed. These were erected in an open recently cut pine area where over 80 percent of the original merchantable stand was removed. Check enclosures, consisting of 6' x 6' x 6' screen cages were set up to compare behavior under the more normal temperature conditions of free air circulation. In all 4 tents (2 shaded by flys and 2 directly exposed to the sun) and 2 screen cages were erected, thus allowing for one replication of a given set of conditions. Included within each enclosure were 5 living small ponderosa pines varying in diameter from 2 to 4 inches to test adult feeding responses. The enclosures were numbered 1A (tent only), 1B (tent with fly), 2A (tent only), 2B (tent with fly), 3A (screen cage), 3B (screen cage).

Air temperatures within all enclosures were measured by recording instruments installed 30 inches above the ground. Records were changed weekly during the course of the experiment.

The Ips adults used were reared from naturally infested unlopped tops resulting from a late spring logging operation. Short logs containing pupae and callow adults were bucked from this material, with an allowance of 30 square feet of infested bark area per enclosure. These logs were upended on the ground and distributed evenly. A reasonable assurance for an estimated 3,000 to 4,500 beetles to emerge in a given setup was thus provided.

The emergence rate, peak, and period in each case was determined through use of small emergence cages enclosing infested logs, each containing 3 square feet of bark surface. Each cage was placed alongside of the temperature recording instrument, as illustrated (Photo.3). Daily records were kept.

TEMPERATURE CONDITIONS WITHIN ENCLOSURES

Table 1 presents information on the maximum temperatures within cages 2B (tent) and 3A (screen cage) for a period of two weeks between July 4 and 16, 1950, at 10 AM, 1 PM, and 5 PM. (Daily minimum temperatures were identical). This comparison is typical of the conditions recorded in the other tents, even in those that were shaded by flys and the other screen cage.

The principal temperature difference under the two situations was during mid-day, between 11 AM and 2 PM, at which time (1 PM) the average divergence was 10.4° F. During this time temperatures within the tent varied between 95 and 106° F., while in the screen cage they varied between 81 and 95° F. The highest temperature recorded during the test period within the tent was 118° F. during the last week when at the same time the cage temperature reached 111° F. For practical purposes in the study of the behavior responses of Ips under the two conditions, these highest temperatures were of no significance since they came too late to affect the experiment.

Table 1. Temperature Conditions in Cages 2B and 3A at Different Times.

Date		Cage 2B					Cage 3A			
		Degrees Fahr.					Degrees Fahr.			
1950	Min.	10 AM	1 PM	3 PM	5 PM	Min.	10 AM	1 PM	3 PM	5 PM
July										
4	67	94	101	90	84	66	94	95	94	89
5	67	89	97	91	86	66	91	82	84	90
6	66	86	97	88	84	65	88	89	88	89
7	62	82	97	90	84	62	86	89	89	89
8	62	84	101	92	84	62	83	87	88	87
9	62	64	95	84	80	58	62	81	83	79
10	58	62	89	82	77	56	68	78	79	74
11	58	72	89	82	77	56	68	78	79	74
12	61	92	101	90	82	61	87	90	89	84
13	64	96	104	94	86	65	92	92	93	89
14	65	98	106	94	86	66	96	95	93	88
15	64	98	106	92	85	65	96	94	92	87
16	63	98	104	92	84	64	91	91	90	85
Aver.	63	87.4	99.4	89.4	83.3	62.6	86	89	89	85.3

EFFECT OF TEMPERATURES ON ADULT RESPONSES

Emergence.

As measured by the emergence cage data, there was no significant difference in association with temperature. The reason was obviously due to the relatively short period of exposure each day to the higher temperatures which did not affect the bark temperature of the logs within the emergence cages. The higher air temperatures affecting beetles emerging into collecting chambers caused considerable mortality there only because of close confinement. Emergence from the logs within the tent and cage enclosures also had no apparent relation to differences in maximum air temperature, because of the same reasons mentioned above.

Flight.

Periodic counts of adults on enclosure surfaces proved to be the only means of determining the number of beetles free to move about at any given time. Suspended tangle-foot smeared cardboard designed to trap beetles, 10 swipes of an 18" muslin frame and 10 swipes of an insect net, all failed in attempts to secure quantitative information.

In general, it was found that the number of Ips adults on tent walls at any given time related to the air temperature within the enclosures. This is shown by the example in Table 2 which records the information from 2 tent and 2 screen cage enclosures.

Table 2. Number of Ips Adults on Walls at Given Temperatures from July 18 to 24.

Temperature °F.	Number of Ips Adults			
	Cage 2A	Cage 2B	Cage 3A	Cage 3B
70-74	9	1	0	11
75-79	22	0	9	34
80-84	74	10	122	55
85-89	74	28	162	46
90-94	63	21	134	22
95-99	9	8	43	0

In each case, it is clearly demonstrated that the temperatures of greatest influence range between 80 and 94° F., with the peak at between 85 and 89°F. Beetles were difficult to find at temperatures above and below this range.

It was found that, as a general rule, in all enclosures more adults were in evidence in the afternoon than in the morning. The record from all 6 cages is presented by Table 3 and shows that in only one cage the number was higher in the morning. This was due to the location which permitted higher morning temperatures than in the afternoon because of shade from some tall trees.

Table 3. Number of Adults on Cage Walls in AM and PM, July 18-24

Cage #	Cage type	Number of Adults	
		Morning	Afternoon
1A	Tent	255	314
1B	Tent	312	298
2A	Tent	96	155
2B	Tent	22	50
3A	Screen	173	307
3B	Screen	70	88
		912	1212

It must be noted that even though high temperatures occurred during the morning hours in most of the tents, emergence from logs lagged behind because of the cooler bark temperatures which tended to warm back by the afternoon period. Hence, the occurrence of more beetles in the afternoon on tent walls is presumably due more to this lag factor than the direct effect on the beetles that had emerged.

Temperatures above 100° F. within tent enclosures appeared to have a profound effect on adult behavior. They would remain quiet on walls, with short flights of 4 to 6 inches only when wind currents caused movement of the walls. Their confinement to shadows cast on the tent walls low down indicated an attempt to avoid the hotter temperatures on unshaded portions higher up. Avoidance of unshaded tent areas may have been induced also by differences in illumination, but generally it was noted that the more illuminated areas were to be sought when temperatures were lower.

Few adults were seen crawling on logs at temperatures above 100° F. and in such cases they were noted to search for shelter. One such adult was observed to enter an exit hole and remain beneath the bark.

Attacks.

Detailed observations within tent enclosures under the different temperature conditions occurring there revealed that (1) without exception in all cages attacks were induced in late afternoon and evening, subsequent to cooling within the evident optimum range of 80 to 94° F.; (2) no attacks were observed to be initiated during the morning hours, but this is not without possibility; (3) temperatures prevalent at different levels in the tent enclosures were influential in limiting the intensity of attack at any given level.

This third point was demonstrated by standing a tall fresh log on end for a period of 15 days in cage 1A during relatively heavy emergence. Recovery of attacking adults was accomplished by removing the bark and recording the number at different levels from the base toward the top. The following tabulation records the number found.

Table 4. Number of Ips adults Recovered at Different Levels Beneath Bark of Six-Foot Log.

Location on Log	Adults Found	Percent
Basal 6 inches	109	28
Next 12 inches	67	18
Next 12 inches	46	12
Remaining 42 inches	157	42
Total	379	100

The attacks made in the upper levels of this log occurred after those made below, indicating that overcrowding below forced later attacks at higher levels.

The same attack trend was recorded from a successfully attacking sapling within the enclosure. The thinner bark of the sapling evidently resulted in greater sensitivity to temperature at the different levels, as illustrated by the following tabulation:

Table 5. Number of Ips Adults Recovered at Different Levels from Sapling

Location	Adults	Percent
Basal 6 inches	37	25
Next foot	41	28
Next foot	25	17
Next foot	15	10
Next foot	6	6
Next foot	7	5
Next foot	8	5
Next foot	4	3
Next foot	1	1
Remaining 4 inches	0	0
Total	147	100

Further evidence of the influence of high temperatures within enclosures on attacks is illustrated by log sections in tent enclosure 2B compared with those in screen cage 3A. The following tabulation of attacks made on logs, each containing three square feet of bark surface, reveals a striking difference which is believed largely due to temperatures prevailing within the enclosures.

Table 6. Comparison of Attacks made in Logs under Different Temperature Conditions.

Tent Enclosure (2B)		Screen Enclosure (3A)	
Log No.	Attacks	Log No.	Attacks
1	14	1	41
2	20	2	38
3	14	3	59
4	16	4	75

These figures reveal that from 3 to 5 times the number of attacks occurred in logs under the temperature conditions within the screen cage as in the logs within the tent enclosure. The temperature factor is believed largely responsible for these differences, although differences in light intensity within the tent enclosure and possible differences in emerging populations may have contributed.

Mating Habits.

Observations under all the conditions of this experiment revealed no information on mating as may be related to temperature. Presumably all mating takes place beneath the bark, hence temperature conditions affecting beetles during flight and attack had no apparent bearing on this habit.

Feeding Habits.

Concentrations of adults within a limited area of bark toward the base of the logs or young trees attacked within the tent enclosures indicate a response to avoid high temperatures rather than a feeding habit. Under these crowded conditions, considerably more feeding than that occurring during egg gallery construction was observed, but this cannot be interpreted strictly as a feeding habit, but a response to the high temperature conditions of the experiment.

Reproduction.

Once beneath the bark, air temperatures had no noticeable effect on the behavior of adults on egg gallery excavation, egg deposition, subsequent brood development, or longevity of adults. Except for intensity of attacks, all broods developed were fully normal with respect to survival and period of development.

DISCUSSION

This test brought to light many of the technical difficulties to be encountered in determining and interpreting temperature responses of adults. Most condemning of the use of tent enclosures was the stratification of temperature conditions at different levels from the ground toward the apex. (This difficulty may be overcome in part by use of fans to circulate the air.) Logs set on the ground were relatively cool compared to air temperature conditions 3 or 4 feet above, and inner bark temperatures were little affected during the period of subjection to high air temperatures.

The apparent concentration of adults on the brighter portions of canvas, following emergence, served to indicate that the light response may have influenced the location of attacks in fresh logs or trees within a given enclosure. However, the differences in attacks at different levels made on any given log were unquestionably due to temperature influences.

Because of the variable conditions found within the tents and the limitations in the time of this experiment to make allowances for them, no positive conclusions are possible. About all that may be said at present is that the following behavior responses of adults to high

temperatures appear to be warranted: (1) that temperatures above the optimum range inducing flight and attacks cause adults to remain relatively inactive; (2) that this range apparently occurs between 80 and 94° F.; (3) that attack intensity and concentrations of attacking adults is related to air temperature in the vicinity of attractive host material; (4) that temperatures above the optimum range evidently did not remain for a period long enough to seriously affect normal adult behavior with a return of more favorable temperatures.

SUMMARY

Temperature studies were undertaken during 1950 on Ips confusus adults in an attempt to determine the causes of periodic outbreaks in reserve ponderosa pine stands in the vicinity of logging slash. Previous studies indicated that temperatures affecting the adult, from emergence to attack, may profoundly influence the subsequent establishment of progeny. An experiment was designed to take advantage of temperatures produced in tent enclosures in the open sun. Large screen cages were used as controls to compare behavior under more normal temperature conditions. The experiment was continued for six weeks during July and August 1950. The principal points learned are listed below.

1. High air temperatures within the tent enclosures were of insufficient duration to have an appreciable influence on emergence.

2. Temperatures developed in tent enclosures were consistently 10.4° F. higher than in cage controls during the middle of the day; they were similar at other times.

3. The number of adults settling on the walls of a given enclosure at a stated time, proved the only means of securing quantitative information on beetles in flight under different temperature conditions.

4. Temperatures evidently having the greatest influence on adult activity (flight and attack) range between 80 and 94° F.

5. Temperatures above this range appeared to induce quiescence.

6. The greatest number of attacks was observed in late afternnon or evening, with the advent of cooling to within the optimum temperature range.

7. Stratification of temperatures within tent enclosures appeared to influence the concentration of attacks to the lower (cooler) levels of a log or tree.

8. The number of attacks induced on logs was 3 to 5 times greater in the control cages than in the tent enclosures.

9. Temperatures within enclosures were not observed to affect mating habits.

10. Concentrations of adults in lower portions of trees or logs were induced by high air temperature, resulting subsequently in more boring

for feeding to the exclusion of egg gallery construction.

11. Normal egg gallery construction and brood development occurred in most logs.

Berkeley, California
June 27, 1951

Photo #3 (13392). Emergence cage within tent enclosure. Beetles emerging in collection jar helped provide information on emergence from infested logs within the enclosure. Temperatures were measured by Friez recording instrument shown on table. Freshly cut short logs, upended on floor of cage (3 showing), received normal attacks.

Photo #4 (13389). Heavy accumulation of borings in bark scales indicates intensity of attacks by Ips on saplings within enclosure.

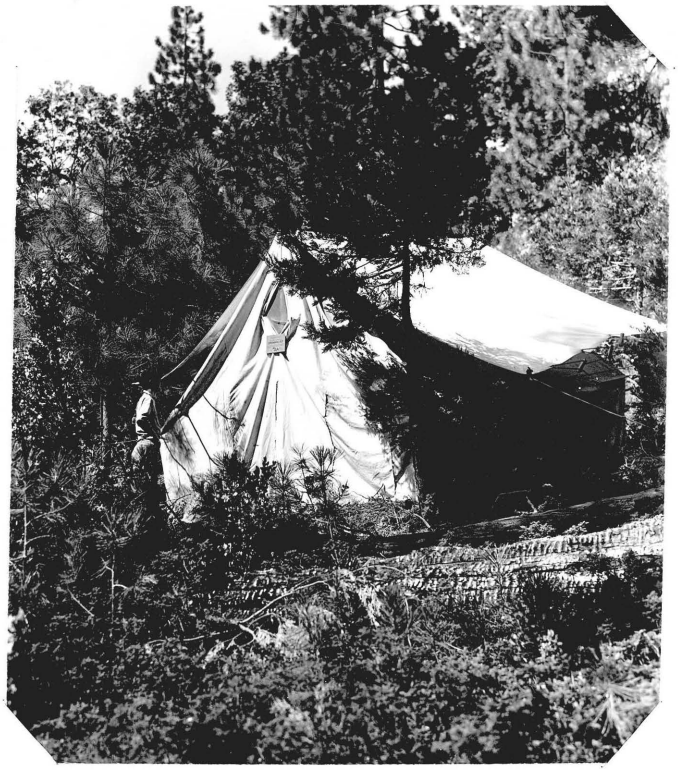

Photo #1 (13393). Tent enclosure used in studying effects of high air temperature on behavior of Ips confusus adults. July 1950.

Photo #2 (13391). Large screen cage employed as control in study of high temperature on behavior of Ips adults. July 1950.